RESEARCH DEPARTMENT

Test card 53:

a test card for checking the spectral sensitivity of image orthicon camera tubes

TECHNOLOGICAL REPORT No. PH-4

UDC 535.6.08:
621.397.61.

1967/10

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

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This Report uses SI units in accordance with B.S. document PD 5686.

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SUMMARY

It has been apparent for some time that a simple and accurate test card is required to test the spectral response of image orthicon camera tubes, and Test Card 53 was devised for this purpose. It consists of six narrow band-pass dielectric filters with peak wavelengths located within the visible spectrum, and two reference filters set to ± 10% of the required spectral response. The signal from the camera tube is displayed as three pulses on a line strobe monitor, enabling comparisons to be made at each of the six wavelengths. In this way the spectral response can be assessed at these six wavelengths in terms of an agreed standard.

1. INTRODUCTION

Although the spectral response characteristic of a monochrome camera tube can be subject to some degree of variation without producing tone reproduction that is in any way unsatisfactory(1), there is nevertheless the need for a fairly precise specification. This is so because several cameras are often used in a studio to obtain different shots of the same subject; variations in spectral response are then translated into variations in the various luminances in the same scene and these can be very obvious on switching from one camera to another. It is, therefore, desirable that a suitable test card shall be available both to the BBC and to camera tube manufacturers so that tube performance can easily be measured. By making the test card available to the manufacturers, a "common language" is obtained which facilitates discussion.

In order to satisfy these requirements Test Card 53 was devised. By simple adaptations, this test card could also be used to test the compliance of a camera tube with any specified spectral response characteristic.

Calculation and calibration of the test card was carried out on the basis of the published English Electric colour response curve of image orthicons(2); the intention being that the test card should enable a comparison in spectral response to be made between a given camera tube under test and the published curve mentioned. This curve (dotted in Fig. 1) is very close to the BBC-preferred colour response "condition 3½"(1), except for blue-violet wavelengths of about 400 to 420 nm.

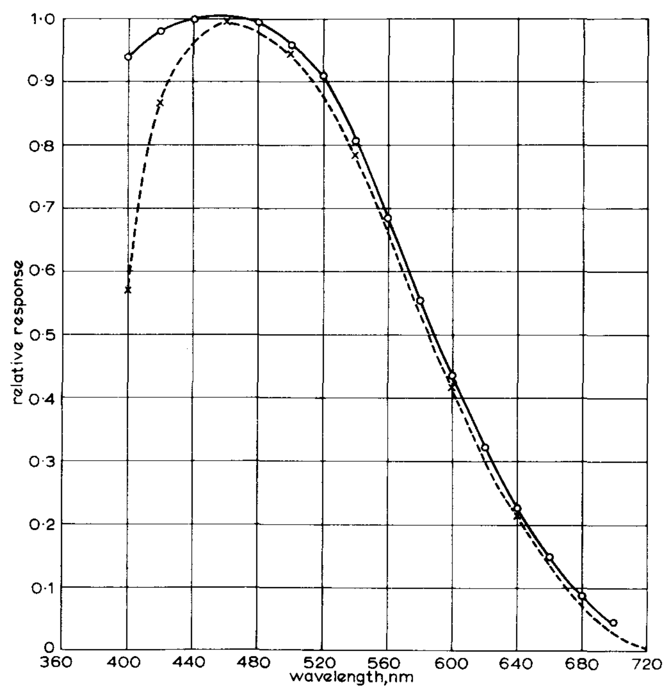

Fig. 1 - Image Orthicon spectral response

——— BBC preferred colour response

– – – – English Electric published curve

2. PRINCIPLE OF THE TEST CARD

The response of a camera tube at any wavelength can be measured by comparing the output of the tube when illuminated by light in a narrow spectral bandwidth with the output obtained from the full spectrum of a tungsten lamp or from a sufficiently wide spectrum of light within the tube's response (it is convenient to make this the blue-green spectral region in the case of the image orthicon).

The spectral range of the tube is sampled by using narrow-band filters at six wavelengths between 400 nm and 700 nm (see Fig. 2). The tube output corresponding to the energy transmitted by each filter will then be proportional to the sensitivity of the tube in the band transmitted by the filter.

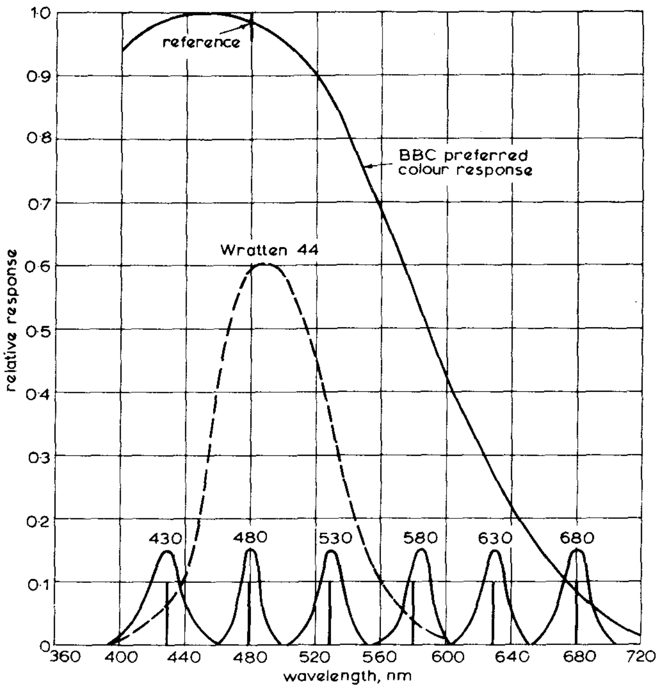

Fig. 2 - Spectral bandwidths of measuring filters
(In practice, the narrow-band filters do not usually have the same peak transmission). The short vertical lines show the nominal values of measurement and reference wavelengths

A wide-band filter (Wratten 44) is used to limit the reference spectrum instead of using the overall response of the tube to tungsten white light. This is desirable because any variations in the spectral response of a given tube (usually in the red region), whilst producing differential variations between the amplitude of the overall output used as a reference and the outputs obtained from the narrow-band measuring filters would also cause the reference itself to vary as a function of the tube spectral response. Now, the image orthicon camera tube has maximum sensitivity and a relatively flat response in the blue-green region (see the dotted curve in Fig. 1). The wide-band reference filter is therefore located in that region in order that the spectral sensitivities of different tubes could be compared. All differences in spectral response can then be referred to that region of the tube response, or in other words, measurements are normalised with reference to peak spectral sensitivity. It is apparent from the graph shown in Fig. 3 that the energy transmitted by the wide-band filter is greatly in excess

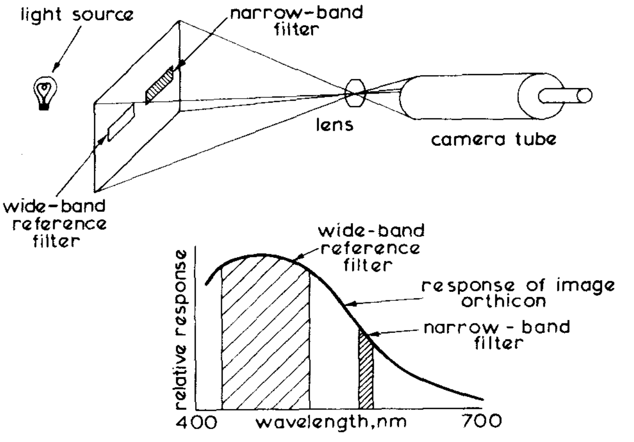

Fig. 3 - Principle of Test Card

of that transmitted by the narrow-band filter. The output from the wide-band filter is therefore suitably attenuated by means of a neutral density filter.

3. DISPLAY OF INFORMATION

It is intended that the information should be displayed on the line strobe monitor used with a camera-tube testing bench[3] by means of a pulse whose amplitude is indicative of the tube response at a given wavelength, and that this pulse be situated between two other reference pulses whose amplitudes correspond to +10% and −10% respectively of the required amplitude (see Fig. 4).

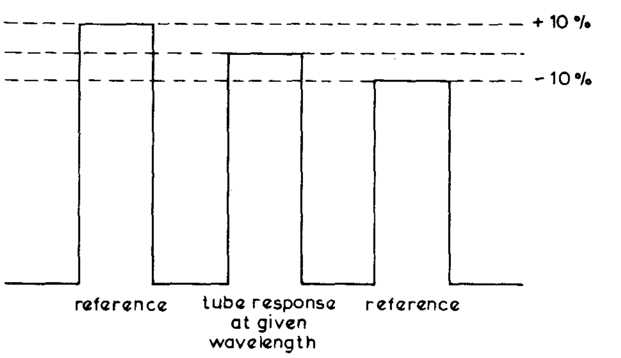

Fig. 4 - Line strobe monitor display

4. COMPUTATION AND CALIBRATION

In computing the test card, a light source of colour temperature of 2360°K was selected for reasons explained in Section 6. As already stated, the camera response curve used was the published English Electric response curve as given in the English Electric catalogue of camera tubes[2].

The transmission curve of the 3 inch Ortal lens used on the camera test bench had to be taken into

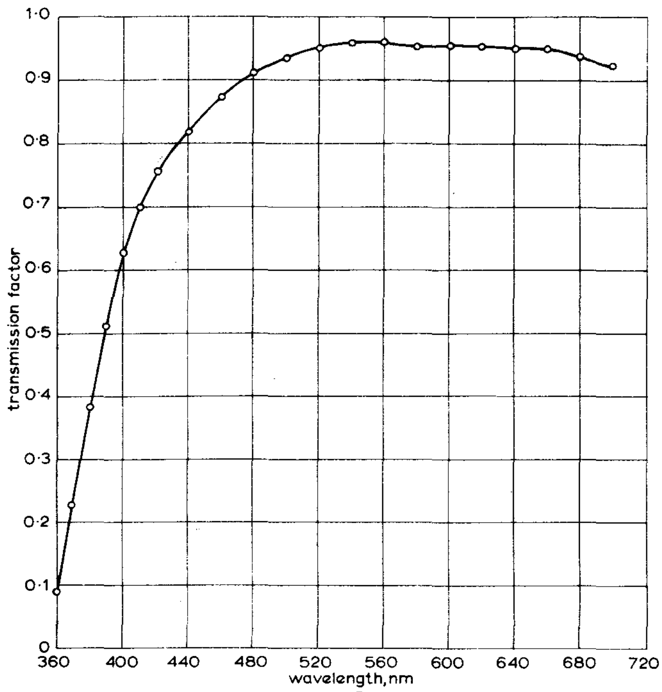

Fig. 5 - Spectral transmission of 76 mm (3 in.) Ortal lens

account since, in common with most lenses, it has a falling transmission characteristic in the blue region (see Fig. 5).

If a narrow-band filter is illuminated by a light source of known energy distribution and the light transmitted is received on a camera tube of known (or specified) colour response, the equivalent neutral density can be calculated (see Appendix). The wide-band filter can then be adjusted to the same value of equivalent neutral density. When viewed by a camera the display of the two resulting pulses will then be equal. Any change in the spectral response of the tube in the region of a narrow-band filter will then be shown as a change in the amplitude of the pulse arising from it in relation to the "wide-band" pulse. In order to ascribe tolerances of acceptable tube response, the transmissions of two reference wide-band filters are adjusted to + 10% and - 10% respectively of the nominal response.

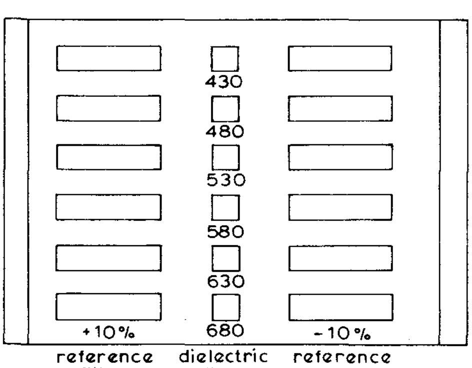

Fig. 6 - First Test Card

The first test card to be made consisted of six narrow-band dielectric filters and associated reference filters as shown in Fig. 6. This test card proved unsuitable owing to variations in sensitivity over the surface of the photo-cathode, non-uniformity of illumination and vignetting by the lens. It was therefore decided to carry out the measurements over a small area at the centre of the tube. To this end the narrow-band filters were mounted on a movable segment as shown in Figs. 7 and 8, in order that each filter could be brought to the same measuring position in turn.

The two wide-band reference filters were adjusted to +10% and -10% of the highest equivalent density dielectric filter (i.e. 430 nm) and neutral filters were added to the other dielectric filters to adjust their overall density in relation to the reference filters. This arrangement has the further advantage of avoiding the need to reset the gain of the waveform monitor for each wavelength since the amplitudes of the reference pulses remain constant.

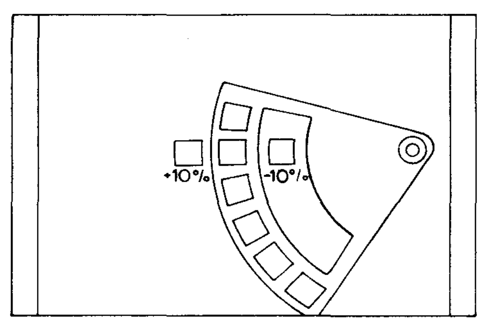

Fig. 7 - Modified Test Card

5. METHOD OF ADJUSTMENT

In practice, when dealing with narrow spectral bands it is extremely difficult to select suitable neutral grey filters because the stated value of density is usually the integrated value over the visual range and over a narrow band the density may well deviate by a considerable amount. Unless an abnormally large selection of neutral filters is available, it is almost impossible to meet all theoretical values to an accuracy better than ·04 in density or 10% in transmission. Further, as each filter would have to be measured on a spectrophotometer, the labour involved would be considerable. Using glass neutral filters would be even more difficult, as grinding and polishing to such accuracy is tedious and lengthy.

In order to make the nine test cards required, one card was made and measured accurately to the computed values then using this card as a standard,

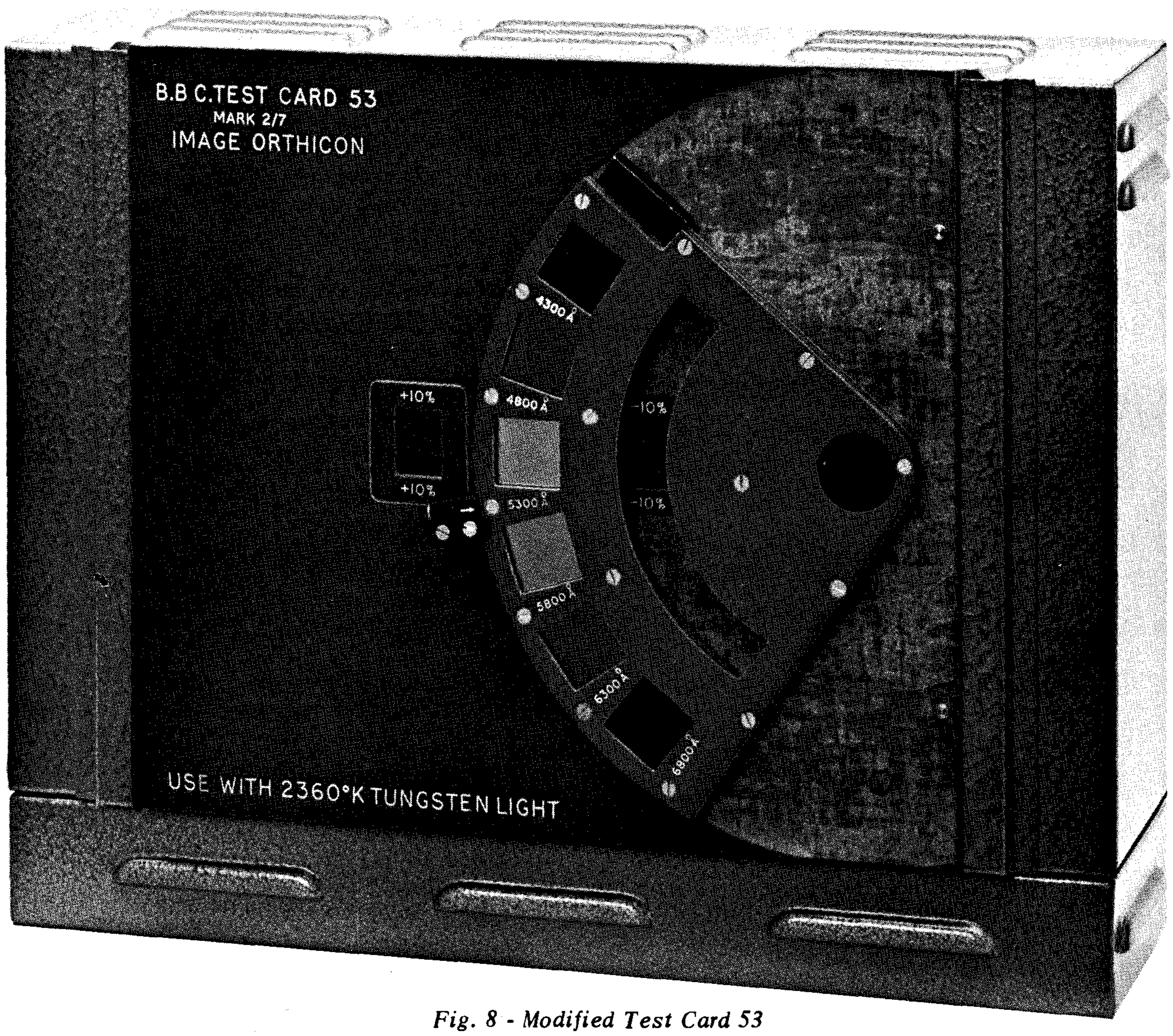

Fig. 8 - Modified Test Card 53

the other eight cards were adjusted on a transmission measuring bench by means of standard neutral grey filters and pieces of plain glass*, (see Fig. 9) to an accuracy of approximately ± 3%.

6. LIGHT SOURCE

The light source is shown in Fig. 10. As already stated, the test card was computed on the basis of a light source operating at a colour temperature of 2360°K (see Fig. 11). This low colour temperature was selected because it is more practicable to adjust the colour temperature of a tungsten lamp at a low value by decreasing its operating voltage than to increase colour temperature by the use of filters, which are usually irregular in spectral transmission over the visible range, and which absorb a significant amount of energy.

* A sheet of unbloomed plain glass has a neutral density of 0·04 due to reflexion at the two surfaces.

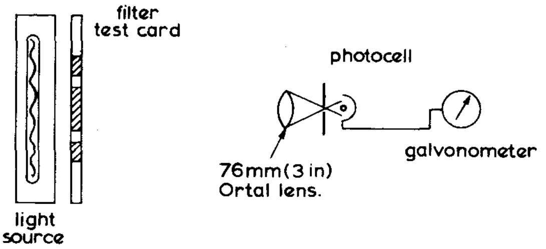

Fig. 9 - Illustrating the method of setting up

In order to produce uniform illumination over the reference and dielectric filters, strip-lamps and diffusing ground glass are used. Because the dielectric filters are of narrow bandwidth the energy transmitted is relatively low and consequently two 40 watt lamps had to be used to give sufficient illumination. A fan was provided for cooling.

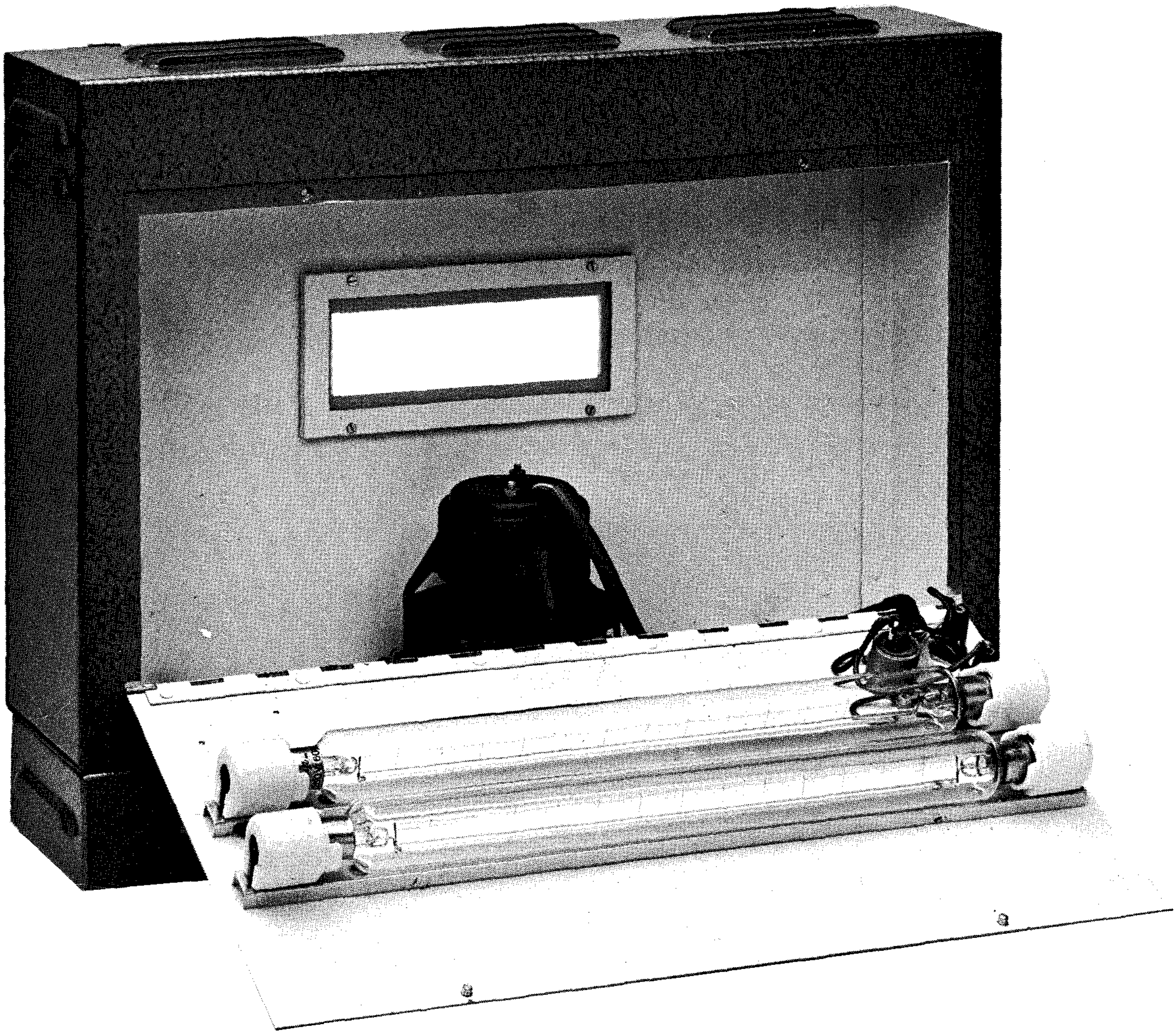

Fig. 10 - Light box: Interior view from the rear showing two 40 watt strip lamps and cooling fan

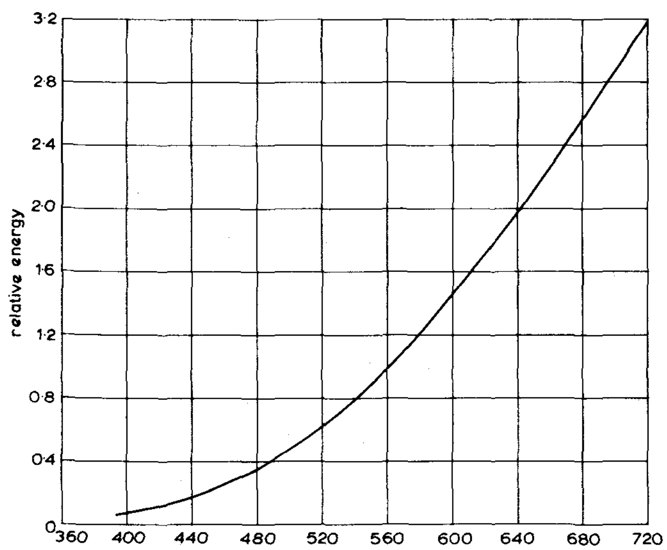

Fig. 11 - Spectral energy distribution of tungsten light source for a colour temperature of 2360° K

7. CONCLUSION

Test Card 53 has been designed on the basis of the published English Electric spectral response curve of the image orthicon, this curve being similar to the preferred response "condition 3½". Tests are now taking place to establish the spread of spectral response characteristics encountered in normal production of image orthicon camera tubes.

From the results already obtained it would appear that the spread is such that the limit of ±10% is unduly severe and it is suggested that limits of ±20% would be more realistic.

By suitable adjustments of neutral density filters and, perhaps, the dielectric filters, this test card can be adapted to other types of camera tube.

8. REFERENCES

1. The colour response of monochrome television camera tubes. BBC Research Department Report No. T-081, Serial No. 1962/2.
2. Data book of English Electric Valves (Television Camera Tubes). English Electric Valve Co. Ltd. Chelmsford.
3. A Test Bench for 4½ inch image orthicon camera tubes. BBC Research Technical Memorandum No. T-1045. May, 1962.

APPENDIX

Determination of Neutral Density Filter Required

It is assumed that the image orthicon is operated below the "knee" and is substantially linear in response.

The camera output signal due to light passing through the reference filter is

$$I_R = k \int E(\lambda)\, L(\lambda)\, S(\lambda)\, F_R(\lambda)\, d\lambda$$

where λ = wavelength

$E(\lambda)$ = spectral emissivity of source (at 2360°K)

$L(\lambda)$ = spectral transmission of the lens

$S(\lambda)$ = relative spectral sensitivity of the image orthicon tube

$F_R(\lambda)$ = transmission characteristic of reference filter

k = constant depending, inter alia, on absolute sensitivity of camera tube.

The camera output due to light passing through the rth narrow-band filter is

$$I_r = k \int E(\lambda)\, L(\lambda)\, S(\lambda)\, F_r(\lambda)\, d\lambda$$

where $F_r(\lambda)$ is the transmission characteristic of the filter and

$$r = 1, 2 \ldots . 6$$

Let the minimum of the quantities I_r be I_n. In fact, it is produced by the blue (λ = 430 nm) filter. Insert a neutral filter of density N into the reference filter such that

$$N = \log_{10}\left(\frac{I_R}{I_n}\right)$$

Add other neutral filters to the remaining narrow-band spectrum filters so that the nominal output is constant (and equal to I_n) if $S(\lambda)$ is as specified for the image orthicon tube.

To obtain the ±10% reference levels, the neutral filter of density N is replaced by two filters of density (N - 0·04) and (N + 0·04) respectively and these are combined with two identical broadband blue-green filters (Fig. 7).

JMP

Printed by BBC Research Department, Kingswood Warren, Tadworth, Surrey